PROJECT AUTHORIZATION NO. HWY-2004-17

under

MASTER AGREEMENT FOR RESEARCH AND TRAINING SERVICES BETWEEN THE NORTH CAROLINA DEPARTMENT OF TRANSPORTATION AND NORTH CAROLINA STATE UNIVERSITY ON BEHALF OF THE INSTITUTE FOR TRANSPORTATION RESEARCH AND EDUCATION
(Contract No. 98-1783)

Project Title: Reasonable Speeds on Improved Curb and Gutter Facilities

Formal Statement of Work: See attached proposal

Period of Performance: July 1, 2003 – December 31, 2004

Budget Authorization: 2003-2004 $59,556, 2004-2005 $46,540

Property to be Furnished by the Department: None

Key Personnel: Principal Investigator: Joseph E. Hummer, Ph.D., P.E.
Co-PI: Billy M. Williams, Ph.D., P.E.

Project Monitor: Mustan Kadibhai, P.E.

Additional Terms and Conditions: Research Project Guidelines as posted on ITRE's website at *http://itre.ncsu.edu/research/ongoingguidelines.htm.*

IN WITNESS WHEREOF, the parties hereto have executed this Project Authorization as of

__________________________, 2003.

NORTH CAROLINA STATE UNIVERSITY

BY:__________________________________
Principal Investigators

BY:__________________________________
N. C. State University

BY:__________________________________
Director of ITRE

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

BY:__________________________________

FY 2004
NCDOT
RESEARCH PROPOSAL

Subcommittee: **Operations**

Project Title: **Reasonable Speeds on Improved Curb and Gutter Facilities, 2004-17**

Submittal Date: **July 10, 2003**

Funding Requested: **FY 2004 $ 59,556, FY 2005 $ 46,540**
Total $ 106,096

Organizations: **North Carolina State University**
College of Engineering and
Institute for Trans. Research and Education

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EXECUTIVE SUMMARY OF PROPOSAL

The NCDOT spends hundreds of millions of dollars each year widening old two-lane roads with 55 mph speed limits into multilane highways. Sometimes on those multilane highways the Department has to construct vertical curbs for access control or other reasons. Since there is clear and well-known guidance that vertical curbs should not be placed next to high-speed lanes, the NCDOT typically uses a lower design speed (50 mph) and posted speed limit (usually 45 mph) on such segments. This lower speed limit creates an enforcement problem, as drivers do not perceive danger from the curbs and try to travel at least as fast as they did before the road was improved.

The NCDOT needs better information to avoid the scenario described above. Specifically, the NCDOT needs answers to two key questions:

1. Do vertical curves next to high-speed lanes really cause more frequent and severe collisions than other cross-section choices? The crash test research is clear, but evidence from collision data is much less convincing.

2. If vertical curbs are more dangerous, is a lower speed limit the best way to alert the public to this danger or are there other treatments that the NCDOT should use?

The purpose of this research is to answer those questions for North Carolina roadways. With answers to those questions, the NCDOT can avoid the unhappy scenario described above.

The main effort in this research will be to find a sample of higher-speed roads with vertical curbs with 45 mph and 55 mph speed limits and examine the collision records and vehicle speed distributions on those roads. The primary research product will be a summary report documenting the answers to the questions and any recommendations based on those answers. The summary report will serve the NCDOT as a technical reference when designing roads with vertical curbs and establishing speed limits on such roads. The report should also be circulated to the State Highway Patrol and other police agencies that enforce those speed limits.

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RESEARCH PLAN

Project Need

The NCDOT spends hundreds of millions of dollars each year widening old two-lane roads with 55 mph speed limits into multilane highways. Sometimes on those multilane highways--due to access control, difficult terrain, limited right-of-way, or other reasons--the Department has to construct vertical curbs. Since there is clear and well-known guidance in the AASHTO "Green Book" and elsewhere that vertical curbs should not be placed next to high-speed lanes, the NCDOT typically uses a lower design speed (usually 50 mph) and posted speed limit (usually 45 mph) on such segments. This lower speed limit creates an enforcement problem, as drivers do not perceive danger from the curbs and try to travel at least as fast as they did before the road was improved. In such a scenario the NCDOT spent millions but many of the participants come away unhappy: most drivers are unhappy about getting tickets or driving slower, other drivers and their passengers become collision victims, and the police are unhappy about the increased enforcement burden.

The NCDOT needs better information to avoid the scenario described above. Specifically, the NCDOT needs answers to two key questions:

1. Do vertical curves next to high-speed lanes really cause more frequent and severe collisions than other cross-section choices? The crash test research is clear, but evidence from collision data is much less convincing.

2. If vertical curbs are more dangerous, is a lower speed limit the best way to alert the public to this danger or are there other treatments that the NCDOT should use?

Research Objectives

The purpose of this research is to answer those questions for North Carolina roadways. With answers to those questions, the NCDOT can avoid the unhappy scenario described above. If the answer to question 1 is "no", the NCDOT can establish a higher speed limit on such sections. In addition, the research may reveal some small design changes, such as a wider outside lane, that may mitigate the collision danger. If the answer to question 2 is "yes", law enforcement agencies are going to have to effectively enforce the speed limit. If the answer to question 2 is "no", some combination of warning devices, for example, may help drivers more than a speed limit.

The research will focus specifically on four-lane roads in developing fringe areas. In more settled urban and suburban areas, curbs with lower speed limits are obviously appropriate. In rural areas, shoulders are usually a better design choice than curbs. The problem described above is typically an interim difficulty for a few years after a new road section is opened but before the roadside develops. The research will examine both four-lane roads with medians and with two-way left turn lanes. The emphasis on four-lane cross-sections is appropriate because the NCDOT rarely rebuilds old two-lane roads in fringe areas into two-lane with curb cross-sections or into six-lane cross-sections.

Literature Review

There is a large volume of literature on crash tests on various types of curbs. These references leave little doubt that vertical curbs next to higher speed roads may cause errant vehicles to become airborne, rollover, or be redirected back into travel lanes (AASHTO, 2001; AASHTO, 2002; Holloway, et al., 1994; Nalecz, et al., 1994; Ross, et al., 1989). There is also a large volume of literature on establishing and enforcing speed limits (TRB, 1998). The consensus from this work is that it is very difficult to enforce a speed limit on a road where drivers do not correctly perceive the danger, particularly on suburban arterial roadways.

For the purposes of this project, the most relevant past research is by other agencies responding to the problem of speeds on curbed roadways in developing fringe areas described above. A search of the on-line databases revealed three agencies that responded to the problem in three different ways. One notable previous study was conducted by the Texas Transportation Institute. They conducted safety studies, operational studies and clear zone studies of various sites in Texas. The safety study looked at collision rates, severities, and characteristics. The operations study addressed shoulder requirements and two-way left turn lane characteristics (Fambro, et al., 1995). The results from these studies were incorporated into the *Texas Roadway Design Guide* (TXDOT, 2002), where they defined a new type of roadway class referred to as a “suburban roadway”. Suburban roadways are high-speed roadways that serve as transitions between low-speed urban streets and high-speed rural highways. Suburban roadways are typically 1 to 3 miles in length and have light to moderate driveway densities (approximately 10 to 30 driveways per mile). Suburban roadways have both rural and urban characteristics. For example, these sections typically maintain high speeds (a rural characteristic) while utilizing curb and gutter to facilitate drainage (an urban characteristic). Consequently, guidelines for suburban roadways typically fall between those for rural highways and urban streets. The *Texas Roadway Design Guide* indicates that the desirable design speed for a suburban roadway is 60 mph with a 2-foot offset from the face of the curb to the traveled path. The minimum design speed to meet their suburban roadway criteria is 50 mph with a 1-foot offset from the travel way to the face of the curb.

The City of Sacramento responded to the same problem in a different way. They engaged the public to help them balance the needs of the different roadway users to develop a design that provided more livable streets. The community-based approach allowed the residents to debate the different issues and gave them a better appreciation of the duties of the roadway agency. The final design incorporated minimum street widths needed for function and safety, rolled curbs with planter boxes and specific standards for specific applications (Ownes, 1999).

The Idaho DOT took yet another approach as they expanded rural, two-lane roadways experiencing 15,000 to 28,000 vehicles per day to four-lane or five-lane facilities. They have completely avoided the curb issue with a new design that provides a rural cross section without curbs, gutters or sidewalks. The speed limit of the facility is 55 mph. They have also developed a five-stage graduated plan to manage access along the corridor that will minimize the expenditure of public funds for right-of-way acquisitions (Carter, 1999).

During the project, the team will contact officials in Texas, Idaho, and Sacramento to gather additional details and follow-up. The team will also conduct a more thorough search for other relevant results, especially collision results, from other agencies.

Research Methodology and Itemized Tasks

The main effort in this research will be to find a sample of higher-speed roads with vertical curbs and examine the collision records and vehicle speed distributions on those roads. These studies will help the researchers answer the first two questions listed above.

After a kick-off meeting with the technical advisory committee to insure that the project team gets moving in the right direction, the project will be conducted as a series of seven tasks:

<u>Task 1, Review Literature.</u> Published literature relating to the safety and speeds on curbed cross-sections in fringe areas will be thoroughly reviewed and summarized. As mentioned above, the project team will contact officials in Texas, Idaho, and Sacramento to gather additional details and follow-up on their various responses to the problem. The team will also conduct a more thorough search for other relevant literature, especially collision results. The team will search electronic databases such as TRIS and will conduct manual searches of the NC State and ITRE libraries.

<u>Task 2, Determine Current Practices and Policies.</u> The object of this task is to understand how design speeds are selected, design elements such as curbs are chosen, and speed limits are set on roadways of interest currently in NC. The project team will build this understanding by conducting telephone, email, and face-to-face interviews with traffic engineers, roadway designers, police officers, and other experts in the area. The team will also review documents used to help in these decisions, such as the NCDOT Roadway Design Manual.

<u>Task 3, Identify Study Segments.</u> The project team proposes to collect valid data on 60 roadway sections in NC with vertical curbs. We will collect data on up to 30 such sections with 55 mph speed limits, although we expect to find fewer than that. The remainder of the sections will have 45 mph speed limits. The team will try to have half of the sample with two-way left turn lanes and half with raised medians. The team will identify sections from the interviews conducted in Task 2, from the NCDOT database of

multilane sections maintained by the Traffic Safety Systems Management Unit, from the results of the current NCDOT research study on four-lane and five-lane cross-sections being conducted by the proposed P.I., and from the ordinance database being assembled by the Traffic Engineering Branch (if it is available in time to help). The team will try to identify up to 75 candidate sections during this task, knowing that the field visits in Task 4 will eliminate some candidates due to construction, errors in databases, and other reasons. To keep the analysis valid, the team will limit sections to at least 0.5-mile long, containing no signals or signal approaches, with no major changes to the cross section.

<u>Task 4, Conduct Field Studies.</u> The project team will visit each sample section identified in Task 3, verify that a vertical curb exists, collect other traffic and cross-section information, and conduct a speed study. The team proposes to use a laser gun to conduct the speed study so that the results are unbiased. The project team will also contact the local police agencies to determine the enforcement tendencies for each section at the time of the speed study and during the three-year collision data period.

<u>Task 5, Obtain and Analyze Collision Data.</u> The project team will examine individual collision reports from three or more years for each study section to determine the number of curb-related collisions. The Traffic Safety Systems Management Unit has a new database that we will use that allows quick examination of individual collision reports. The analysis will try to relate the number of curb-related collisions to the speed distribution and other data from Task 4. We will compare collision frequencies, severities, and characteristics between similar sections with 45 mph and 55 mph speed limits. We will also look for design characteristics such as wider outside lanes that might contribute to lower collision frequencies or severities in combination with vertical curbs.

<u>Task 6, Investigate Alternative Practices and Policies.</u> If some change in current practices appears warranted based on the results from previous tasks, the project team will explore alternatives during this task. This task might require additional literature search, on a topic not reviewed during Task 1 or additional interviews with traffic engineers, police, or other experts.

<u>Task 7, Write Report.</u> We will prepare a final summary report highlighting the project's key findings and recommendations. All supporting information including a full data set, interview notes, collision analysis details and interim findings will be organized in appendices to the final report.

ANTICIPATED RESULTS AND SIGNIFICANCE

The research will provide answers to the questions listed above and recommendations based on those answers. The results will be quite significant for the NCDOT and its highway users. Among the possibilities are:

- There is a collision effect, so the rebuilt sections should be posted at 45 mph. The NCDOT will be able to answer critics of the speed limit, and the police agencies charged with enforcing the speed limits will be encouraged to do so vigorously.

- There would be a collision effect, but some design characteristics or practices could change that would allow the speed limits of these sections to be 55 mph safely. The NCDOT will need to make changes to its design manuals and will need to educate its designers to implement this type of change.

- There is no collision effect, so the rebuilt sections should be posted at 55 mph. Drivers will save time, police agencies will be able to concentrate enforcement resources at more critical locations, and the NCDOT will enjoy positive public relations in these cases.

The summary report will serve the NCDOT as a technical reference when designing roads with vertical curbs and establishing speed limits on such roads. The report should also be circulated to the State Highway Patrol and other police agencies that enforce those speed limits.

RECOMMENDATIONS FOR IMPLEMENTATION AND TECHNOLOGY TRANSFER

- What is the primary product? The primary product from this research will be answers to the two questions posed above, and recommendations based on those answers.

- What are the secondary products? Secondary products from this research will include additional information on the safety effects of four-lane design features, such as the effects of medians versus two-way left turn lanes, superelevation rates, and lane widths.

- Who within NCDOT will use the products? Highway designers and traffic engineers will use the results to choose design features for new four-lane sections and choose appropriate speed limits and other traffic control devices.

- Why should they use the products? Highway designers and traffic engineers will use the results from this research because they currently face a real and frustrating gap in the knowledge base regarding four-lane highways with curbs in fringe areas.

- How will they use such products? The results from this research will be simple to use, in the form of changes to design manuals and speed limit criteria.

- What is needed for NCDOT customers to use the products? Once the research is complete, the NCDOT will only need to make a few changes to its design manuals and speed limit criteria and inform its designers and traffic engineers of the changes.

RESOURCES TO BE SUPPLIED BY THE NCDOT

Besides advice supplied by the technical advisory committee and others contacted during various tasks, the only resource to be supplied by the NCDOT during the project will be access to collision, inventory, and other databases.

TIME REQUIREMENTS

We plan to complete the project within 1.5 years—by December 31, 2004. This will provide the NCDOT with the information it needs as quickly as possible. This condensed schedule is possible because the data collection may be performed during any season, as long as the sample sections are clear and dry, and because the data collection is just a one-person operation. Figure 1 shows the complete task-by-task schedule.

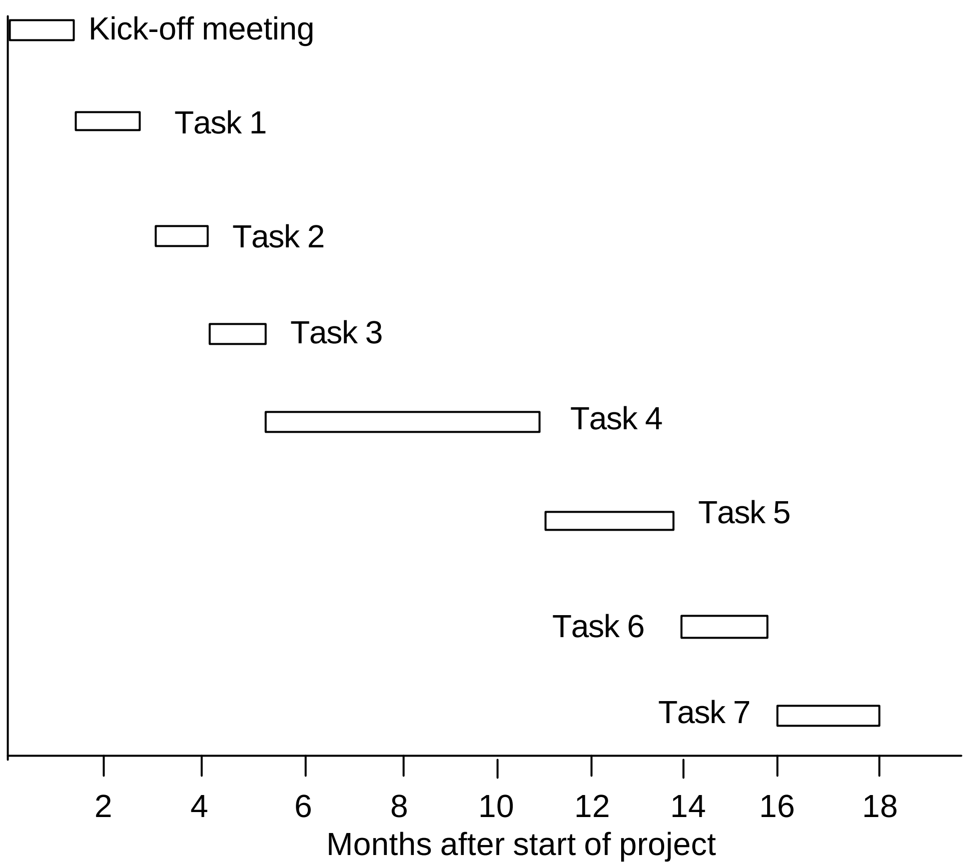

Figure 1. Project schedule.

QUALIFICATIONS AND ACCOMPLISHMENTS OF RESEARCHERS

NC State has assembled a highly-qualified team to conduct the proposed research. The Principal Investigator is Joseph E. Hummer, Ph.D., P.E., who will be responsible for the overall direction of the project. He will spend the majority of his time on the data analysis and report writing. Billy M. Williams, Ph.D., P.E. will serve as a Co-Principal Investigator. He will provide advice on all aspects of the project, and his main emphasis area will be in sample site selection using the various NCDOT databases. Chris Cunningham of ITRE will serve as Staff Engineer on the project and will concentrate on managing the field data collection and gathering information on current practices in the area. Rounding out the research team will be a graduate research assistant, likely at the Masters level. A short summary of the qualifications of the PI and Co-PI is provided below.

Joseph E. Hummer, Ph.D., P.E., the proposed Principal Investigator, is Associate Professor of Civil Engineering at NC State University, where he has taught and researched traffic operations and safety for 11 years. Previously, he was on the faculty at UNC Charlotte, worked for a consulting company, and served as a Graduate Research Fellow at the Federal Highway Administration. Dr. Hummer has authored or co-authored 40 papers for peer-reviewed journals and numerous other reports and articles. Dr. Hummer has served as PI on six past NCDOT research projects and is serving as PI on two current NCDOT research projects. In the safety area, Dr. Hummer helped assemble one of the first collision models of highway cross-sections to gain wide acceptance in the U.S. He has also examined the safety of three-lane versus undivided four-lane cross-sections in suburban areas, and is currently looking at four-lane divided versus five-lane cross-sections. Dr. Hummer is also currently a member of the project team on the FHWA study using GPS receivers in a large sample of probe vehicles in the Atlanta area to model drivers' speed choices on various types of highways with different traffic conditions. Dr. Hummer is an accomplished and experienced user of collision data, having written the chapter on "Accident Studies" for ITE's *Manual of Transportation Engineering Studies*, the nation's premier reference on traffic data collection.

Dr. Billy M. Williams, P.E. is an Assistant Professor of Civil Engineering at NC State. He joined the NC State faculty in August 2002 after serving three years on the civil engineering faculty at Georgia Tech. Prior to his doctoral studies at the University of Virginia, Dr. Williams was a consulting engineer and project manager for Kimley-Horn and Associates for 5-½ years. His consulting work covered the full range of transportation planning, operations and design including projects such as:

- Master planning for the NC Global Transpark
- Concept design for roadway and streetscape improvements in the Waterside/Nauticus area of Norfolk
- Signal system feasibility studies for the Burlington/Graham and Salisbury urban areas

Dr. Williams' consulting work also included numerous traffic engineering and safety studies throughout North Carolina and in other states including Michigan, Illinois, Alabama and Arkansas.

Dr. Williams' has contributed to six archival journal articles in addition to numerous technical reports, conference proceedings and invited seminars. His research focus is in the optimization of the efficiency and safety of traffic operations with emphasis on:

- Traffic flow theory
- Traffic modeling and simulation
- Applied statistics using dynamic and archived traffic data

He served as principal investigator for a guardrail delineation project for the Georgia DOT and was instrumental in establishing intelligent transportation systems research labs at the University of Virginia and Georgia Tech. In 2002, Dr. Williams was awarded a National Science Foundation *Faculty Early Career Development* grant for his proposal titled "System-wide Traffic Condition Monitoring and State Estimation for Intelligent Transportation Systems."

OTHER COMMITMENTS OF RESEARCHERS (AS OF JULY 1, 2003)

<u>Hummer</u>

- Operations of Shared Use Paths, FHWA, October 2000-September 2003 (10% of time).
- Communicating Changes in Horizontal Alignment, NCHRP, January 2001-August 2003 (7% of time).
- Railroad Crossing Wayside Horn Evaluation, NCDOT, July 2002-June 2004 (6% time).
- False Capacity for Lane Drops, NCDOT, July 2002-June 2004 (15% of time).
- Effects of Increased U-Turns at Intersections on Divided Facilities and Median Divided Versus Five-Lane Undivided Benefits, NCDOT, July 2002-June 2004 (12.5% of time)
- I-40 Reversal Operational Traffic Analysis, NCDOT, July 2003-June 2005 (3% of time)

<u>Williams</u>

- CAREER - System-wide Traffic Condition Monitoring and State Estimation for Intelligent Transportation Systems, NSF, June 2002-May 2007 (8% of time)
- I-40 Reversal Operational Traffic Analysis, NCDOT, July 2003-June 2005 (10% of time)

CITED PUBLICATIONS

1. AASHTO, *A Policy on Geometric Design of Highways and Streets*, Washington, DC, 2001.

2. AASHTO, *Roadside Design Guide*, Washington, DC, 2002.

3. Carter, H., “ A Local Government’s Experience with Planning and Implementing an Access Management Plan.” ITE, Washington DC, 1999.

4. Fambro, D.B., et al., “Geometric Design Guidelines for Suburban High-Speed Curb and Gutter Roadways,” Final Report, FHWA/TX-95/1347-1F, Texas DOT and FHWA, Austin, May 1995.

5. Holloway, J.C., et al., “Performance Evaluation of NDOR Mountable Curbs,” Final Report, Nebraska Department of Roads, Lincoln, June 1994.

6. Nalecz, A.G., et al., “Effects of Light Truck and Roadside Characteristics on Rollover,” HS-808 408, NHTSA, Washington, DC, December 1994.

7. Owens, G. “Developing Street Standards that Allow Flexibility.” Transportation Research Circular, Washington DC, June 1999.

8. Ross, H.E., et al., *Roadside Safety Design for Small Vehicles*, NCHRP Report 318, Washington, DC, May 1989.

9. Texas Department of Transportation, *Roadway Design Manual,* Design Division, Roadway Design Section, Austin, October 2002.

10. TRB, *Managing Speed: A Review of Current Practice for Setting and Enforcing Speed Limits*, Special Report 254, Washington, DC, 1998.